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## **Bone and cartilage wedge technique in posttraumatic enophthalmos treatment**

Lieger, O ; Zix, J ; Kruse, A ; Goldblum, D

**Abstract:** **OBJECTIVE:** To evaluate a new surgical method, using calvarial bone graft combined with a wedge of irradiated homologous costal cartilage, for the revision repair of posttraumatic enophthalmos. **METHODS:** This retrospective study was performed from January 1, 2003, through December 31, 2007. Eight patients were diagnosed as having unilateral posttraumatic enophthalmos. All the patients had previously undergone insufficient primary repair of their orbital fractures. In the revision surgery a calvarial bone graft was placed in the area of the defect using a transconjunctival approach. In combination with this technique, a wedge of irradiated rib cartilage was placed on the bone graft behind the globe. Patients were assessed preoperatively and postoperatively by ophthalmologists and maxillofacial surgeons. Standard follow-up examinations were performed at 2 and 4 weeks and at 3 and 6 months after surgery. Computed tomographic scans were obtained preoperatively and postoperatively from all patients. **RESULTS:** For all 8 corrected orbits, favorable cosmetic results were obtained regarding the position of the globe. The mean preoperative Hertel exophthalmometer showed a difference of 3.1 mm and 0.7 mm postoperatively. Improvement of ocular motility and reduction of diplopia were achieved in only 1 patient; in the others, motility and diplopia remained unchanged. No postoperative complications were observed. **CONCLUSION:** The bone and cartilage wedge technique seems to be a useful surgical technique for the cosmetic correction of posttraumatic enophthalmos.

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# Bone and Cartilage Wedge Technique in Posttraumatic Enophthalmos Treatment

Olivier Lieger, MD, DMD; Jürgen Zix, MD, DMD; Astrid Kruse, MD, DMD; David Goldblum, MD; Tateyuki Iizuka, MD, DDS, PhD

**Objective:** To evaluate a new surgical method, using calvarial bone graft combined with a wedge of irradiated homologous costal cartilage, for the revision repair of posttraumatic enophthalmos.

**Methods:** This retrospective study was performed from January 1, 2003, through December 31, 2007. Eight patients were diagnosed as having unilateral posttraumatic enophthalmos. All the patients had previously undergone insufficient primary repair of their orbital fractures. In the revision surgery a calvarial bone graft was placed in the area of the defect using a transconjunctival approach. In combination with this technique, a wedge of irradiated rib cartilage was placed on the bone graft behind the globe. Patients were assessed preoperatively and postoperatively by ophthalmologists and maxillofacial surgeons. Standard follow-up examinations were performed at 2 and 4 weeks and at 3 and 6

months after surgery. Computed tomographic scans were obtained preoperatively and postoperatively from all patients.

**Results:** For all 8 corrected orbits, favorable cosmetic results were obtained regarding the position of the globe. The mean preoperative Hertel exophthalmometer showed a difference of 3.1 mm and 0.7 mm postoperatively. Improvement of ocular motility and reduction of diplopia were achieved in only 1 patient; in the others, motility and diplopia remained unchanged. No postoperative complications were observed.

**Conclusion:** The bone and cartilage wedge technique seems to be a useful surgical technique for the cosmetic correction of posttraumatic enophthalmos.

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ORBITAL FRACTURES ARE REPORTED in approximately 20% to 40% of maxillofacial injuries and therefore represent 1 of the most commonly encountered types of midfacial fracture.<sup>1,2</sup> A trauma to the orbit with bony displacement and soft tissue lesions accounts for serious sequelae, including diplopia, ocular muscle entrapment, and enophthalmos.<sup>3</sup> Different causes of posttraumatic enophthalmos have been previously discussed, such as increase of the bony orbital volume, soft tissue contracture, and fibrosis.<sup>4</sup> Orbital fat atrophy was believed to be the central cause of enophthalmos,<sup>5</sup> but in a study by Ramieri et al,<sup>6</sup> this assumption could not be proven. The main problem seems to be the changes in the orbital volume (increase of container volume). Ramieri et al<sup>6</sup> also found that the shape of the posterior segment of the orbit changes from conical to more rounded because of enlargements. Therefore, the goal of operative reconstruction is to free entrapped tissue and to reconstruct the orbit in an anatomical correct order, focusing especially on this posterior segment.<sup>6,7</sup>

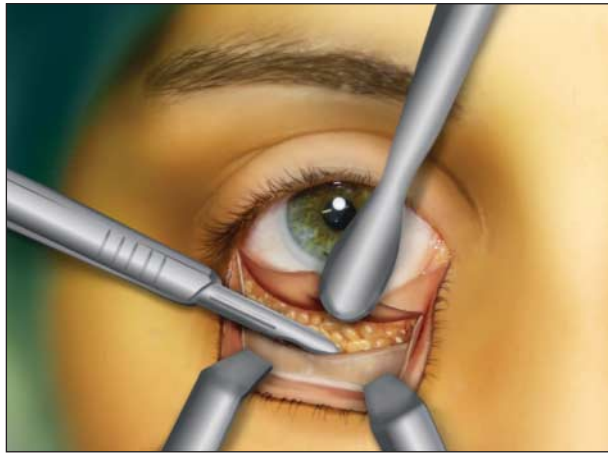
We present the results of an effective and simple approach to restoration of the orbit in posttraumatic enophthalmos by inserting a single piece of calvarial bone in combination with a sickle-shaped wedge of irradiated rib cartilage. Because stiffness of the calvarial bone makes it difficult to obtain an optimal result, we also insert a piece of malleable cartilage on top of the bone transplant. The cartilage is easy to sculpt and resistant to resorption. Forming the cartilage in a sickle-shaped wedge not only reduces the volume in the posterior third but also forces the globe forward and upward.

## METHODS

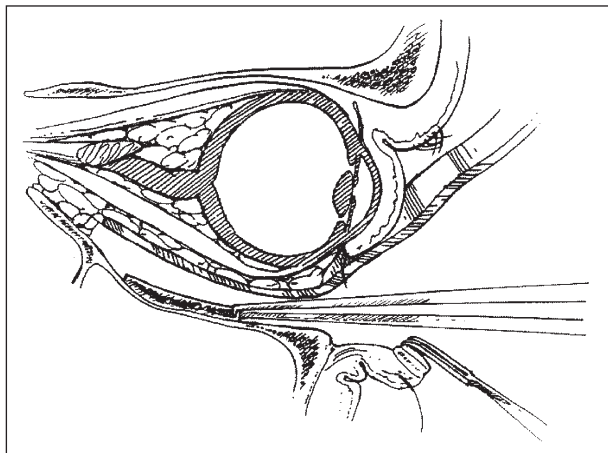
From January 1, 2003, to December 31, 2007, 8 patients underwent orbital revision surgery for unilateral posttraumatic enophthalmos with or without diplopia. A side difference of 2 mm or more, measured by Hertel exophthalmometry, was considered enophthalmos.<sup>8,9</sup> All patients were examined preoperatively and postoperatively by ophthalmologists and maxillofacial surgeons. The extent of the fracture and the postoperative position of the implants were assessed with the help of preop-

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**Figure 1.** Transconjunctival approach to the orbital floor.



**Figure 2.** Insertion of the calvarial bone graft. Sagittal view of the orbit with insertion of the calvarial bone graft via the transconjunctival approach.

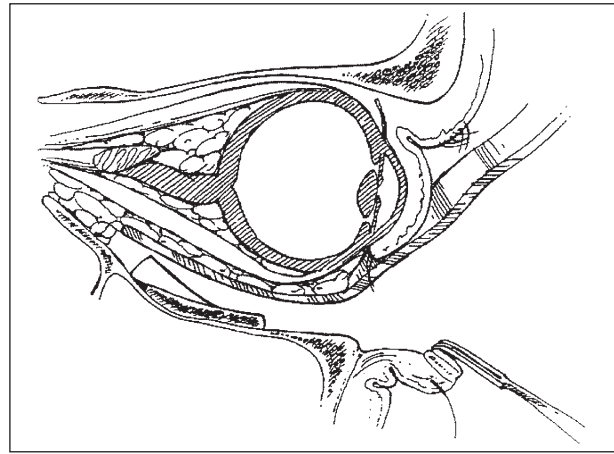
eratively and postoperative computed tomographic scans. The extent of enophthalmos was quantified with a Hertel exophthalmometer (Mirror-Exophthalmometer; OCULUS Inc, Lynnwood, Washington). Diplopia was determined using the Harms wall; ocular motility was evaluated by assessment of 8 fields of gaze and the forced duction test. In all patients standard follow-ups at 2 and 4 weeks and at 3 and 6 months were performed by the maxillofacial surgeon (O.L. or I.T.). Ophthalmologic follow-up was performed between 5 and 7 months postoperatively on a routine basis. For the analysis, the most recent orthoptic and ophthalmologic examination results were used in this study.

### EXPOSURE

During surgery, a vasoconstrictor is injected under the conjunctiva. Access to the orbital rim can be achieved through different approaches. We favor the transconjunctival incision with or without lateral canthotomy for better exposure of the lateral orbit (**Figure 1**). The medial wall area can then be assessed by a transcaruncular or precaruncular approach. Subciliary or lower lid or midtarsal incisions are alternatives to the transconjunctival approach.

### MOBILIZATION OF ORBITAL CONTENTS

Extensive subperiosteal dissection in the area of the injury up to 1 cm to the orbital apex is performed to free the periorbital



**Figure 3.** Orbit with calvarial bone and cartilage graft. Sagittal view of the orbit with the calvarial bone and cartilage graft in place.

tissue. Care is taken to avoid damaging the lacrimal sac. The inferior fissure is dissected free for better mobilization of the orbital content. No important structures are damaged by this procedure. For the same reason, the anterior ethmoidal artery is coagulated with bipolar diathermy or clipped and divided. Intact bony edges are then identified: they will serve as the construction basis for the grafts. The dissection can be difficult, especially for patients in whom surgery has been delayed or not performed at all, for whom prolapsed periorbital tissue has scarred the maxillary sinus. Careful and extensive dissection is then required to free the periorbital tissue without causing any damage to the infraorbital nerve. Once the prolapsed tissue is repositioned, it can be retracted with brain retractors or silicon sheets. This allows easier control during placement of the grafts. The posterior ethmoidal artery marks the dorsal border of dissection. Because of the close anatomical relation to the optic nerve, to avoid optic nerve injuries further dissection should not be performed.

### ORBITAL REPAIR

The optimal size of the calvarial bone graft is estimated and marked on a paper template. The skullcap is exposed by the unicoronal approach and a piece of calvarial bone harvested. The bone graft is then shaped as necessary to fit the bony defect. It is then inserted into the orbit and fixed with screws or miniplates (**Figure 2**). Instead of using multiple grafts in an onlay fashion, a lyophilized cartilage rib graft is used to reduce the remaining spare volume and to push the globe forward. For this purpose the cartilage graft is carved to a sickle-shaped wedge and placed behind the globe without fixation (**Figure 3** and **Figure 4**). A slight overcorrection is aimed for because intraoperative swelling of the soft tissue has to be taken into consideration. To avoid restriction of the inferior rectus muscle, attention has to be paid to the height of the posterior edge of the cartilage graft. Finally, the position of the globe is assessed clinically. Motility of the eyeball is checked using the forced duction test.

### PERIOPERATIVE MANAGEMENT

Preoperative and regular postoperative ophthalmologic assessments are required to detect ocular hypertension or pressure-related lesions of the optic nerve as soon as possible. For prophylactic reasons, 3 doses of amoxicillin and clavulanic acid (1.2 g) are administered intravenously: the first dose intraoperatively, and the second and third in the following 24 hours.

For the following 5 days, the treatment is continued with 2 doses of amoxicillin and clavulanic acid (1.0 g) orally. No steroids are applied.

## RESULTS

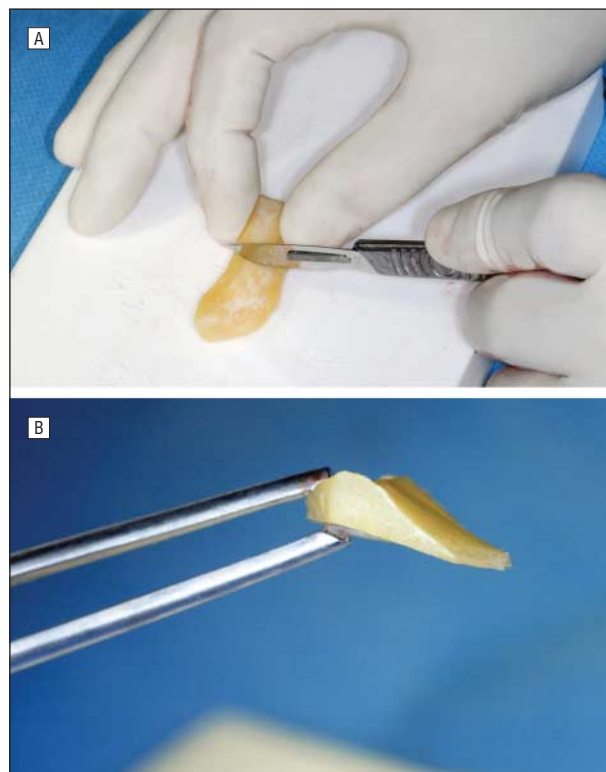
Eight patients were included in the study (4 men and 4 women; age range, 19.7-51.5 years; mean age, 31.1 years) (**Table**). The initial surgical treatment of the fractures was performed within 1 to 19 days (mean, 7.5 days). Polydioxanone (5 patients) or polyglactin 910 and polydioxanone patch (Ethisorb; Codman & Shurtleff Inc, Raynham, Massachusetts) (3 patients) implants were inserted in the primary reconstruction regions. The time delay between the first operation and the secondary surgical correction of the enophthalmos ranged from 1 month to 7 years 5 months (mean, 2.2 years). Two patients sustained pure blowout fractures, and the remaining 6 had associated zygomaticomaxillary (n=4) or naso-orbito-ethmoidal (n=2) fractures. The defect size was measured using computed tomographic scans and verified intraoperatively. It ranged from 3 to 6 cm<sup>2</sup> (mean, 4.2 cm<sup>2</sup>).

Preoperatively impaired ocular mobility was seen in 6 and diplopia in 5 patients. Hertel exophthalmometer assessment showed a mean preoperative difference of 3.1 mm (range, 2.0-6.0 mm). All of our patients with diplopia had a positive forced duction test result preoperatively. Intraoperative forced duction test results showed improved motility in all patients. Ophthalmologic follow-up was performed between 5 and 7 months postoperatively routinely. The mean follow-up was 29 months (range, 12-43 months). Improvement of ocular motility and reduction of diplopia was found in 1 patient (**Figure 5** and **Figure 6**). In 5 patients diplopia remained unchanged. One of the patients without double vision preoperatively developed transient diplopia, which settled within 4 months. The last Hertel assessment showed a mean difference of 0.7 mm (range, 0.0-2.0 mm) (**Figure 7**). Clinical follow-up examination at 2 and 4 weeks and 3 and 6 months by the maxillofacial surgeon showed favorable wound healing in all patients with no signs of infection. Partial infraorbital nerve paresthesia was present preoperatively in all patients and remained unchanged after surgical repair. The transconjunctival incision did not cause any complications, such as ectropion or entropion.

Postoperative computed tomographic scans showed favorable restoration of the inner boundary of the orbit with adequate correction of the bulb position. Volume analysis turned out to be unsatisfactory because it was not possible to identify the exact borders of the cartilage implant. Four of the patients with persistent diplopia underwent successful strabismus surgery within the postoperative year.

## COMMENT

Late enophthalmos and persistent diplopia are severe complications after orbital injuries. To avoid these sequelae, early repair of orbital fractures has become a standard procedure in most patients.<sup>10-12</sup> Several implants for or-



**Figure 4.** Intraoperative carving of cartilage. A, Cutting of the lyophilized rib cartilage into the size required. B, Final wedge shape of the cartilage before placing it into the orbit.

bital repair are available today, all of which have their advantages and disadvantages. We, however, have stopped using polydioxanone foils in orbital repair because of unsatisfactory results presented in the literature<sup>13,14</sup> and seen in our follow-up assessments. We now prefer to use Ethisorb in small and bioresorbable polylactide plates or titanium mesh in larger fractures. Other implants may certainly be equally adequate.

Posttraumatic enophthalmos is caused by enlargement of the orbital volume, mainly owing to missed diagnosis or incorrect reconstruction.<sup>6</sup> Therefore, the treatment of these patients must focus on the repair of the anatomical size of the orbit. In the delayed repair of orbital trauma, it is, however, extremely difficult to reconstruct the original size of the orbit because of bone remodeling and scarring. Fine adjustments that must be performed intraoperatively remain a major challenge to virtually any surgeon. Three typical surgical methods are used to treat enophthalmos: osteotomies of the orbital walls (often in combination with navigation surgery devices), insertion of alloplastic implants, or insertion of autologous bone. In patients with osteotomies, the repair of the orbit with the original bone is often not feasible because of resorption. Even with the help of a navigational system, bony gaps cannot be avoided and must be closed with the insertion of implants. In addition, navigation surgery is still an expensive method and is not available to every surgeon. Several alloplastic materials, including titanium, silicone, Teflon (E.I. du Pont de Nemours and Company, Wilmington, Delaware), polytetrafluorethylene, and methylmethacrylate polymers,



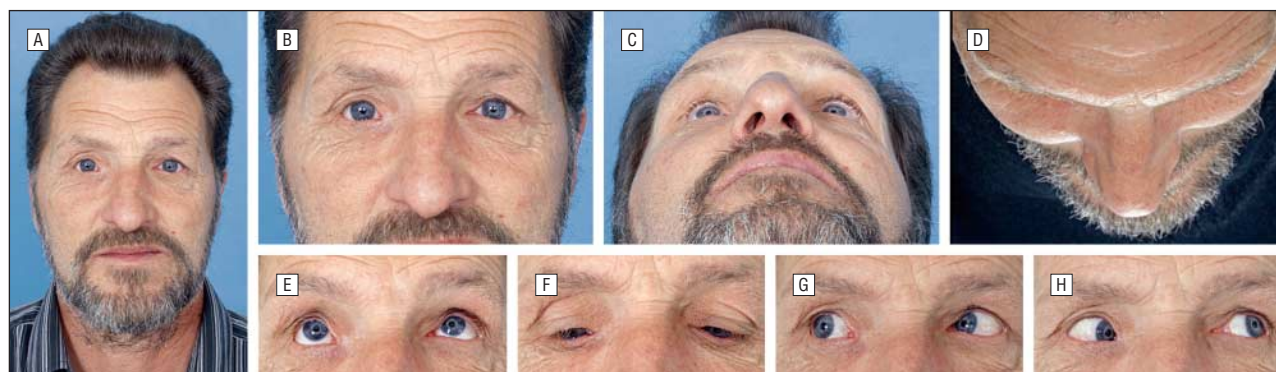
**Table. Patient Data**

Characteristic	Patient No.							
	1	2	3	4	5	6	7	8
Age, y	28	35	25	51	22	31	19	46
Sex	F	F	F	M	M	F	M	M
Type of fracture	Zygomatic complex	Zygomatic complex	Zygomatic complex	Blowout	Panfacial	Blowout	NOE	NOE
Preoperative findings								
Diplopia	Yes	No	Yes	Yes	Yes	Yes	No	Yes
Enophthalmos: Hertel difference, mm	2.0	2.5	3.0	2.0	3.0	3.0	3.0	6.0
Gaze restrictions	Lateral	Lower	Upper	Upper and lateral	Upper	Upper	None	Upper and lateral
Postoperative findings								
Diplopia	Yes	No	Yes	Yes	No	Yes	No	Yes
Enophthalmos: Hertel difference, mm	0	0	0	1.0	1.0	1.0	1.0	2.0
Gaze restrictions	Lateral	Lower	Upper	Upper	None	Upper	None	Upper and lateral

Abbreviations: F, female; M, male; NOE, naso-orbito-ethmoidal fracture.



**Figure 5.** Preoperative clinical pictures of a patient who has enophthalmos, hypoglobus, and restricted eye motility in all 4 directions. A, Front view of face. B, Front view of midface. C, View from below. D, View from above. E, Upper gaze. F, Lower gaze. G, Abduction. H, Adduction.



**Figure 6.** Postoperative clinical pictures of patient, who shows improved sagittal and horizontal globe positioning and improved motility in upper gaze and abduction. A, Front view of face. B, Front view of midface. C, View from below. D, View from above. E, Upper gaze. F, Lower gaze. G, Abduction. H, Adduction.

have been used for volume and structural augmentation in the orbit. Use of these synthetic materials, however, is more likely to result in infection, extrusion, and the initiation of an inflammatory response, including fistula and cyst formation, compared with autogenous grafts.<sup>15,16</sup> Autogenous grafts are commonly harvested from the skull, rib, or iliac crest. However, endochondral bone, such as from the rib or iliac crest, is partially resorbed over time; postoperative pain and local hematoma are sig-

nificant complications at the donor site. In membranous bone, such as calvarial bone, the donor site morbidity is minimal. The procedure described is a simple method for obtaining a graft, which is said to have a low rate of postoperative absorption.<sup>17,18</sup> A big disadvantage, however, is the limited malleability of the calvarial bone, which makes restoration of the correct anatomical situation of the orbit more difficult. For optimal restoration of the orbit, the grafts should be placed behind the eye-

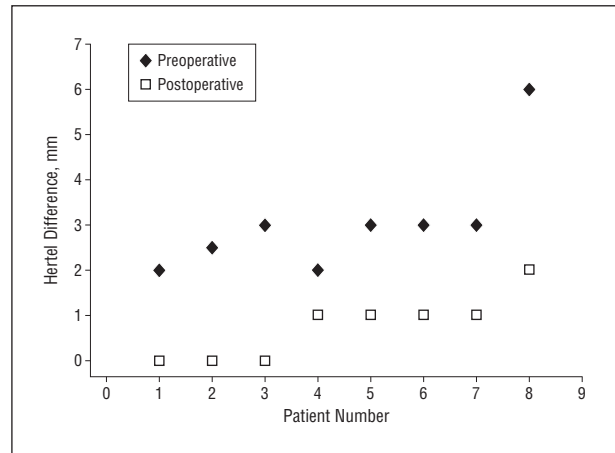
ball.<sup>6,7</sup> To achieve an optimal result, some surgeons<sup>19</sup> insert multiple layers of bone grafts in the posterior third, whereas others<sup>5</sup> prefer to cut the graft into sections and plate the pieces in the desired shape. To our knowledge, the outcomes of these procedures have not been published. In our hands, these techniques showed some disadvantages. It turned out to be especially difficult to perform fine adjustments using multiple layers of compact bone fixed to each other with screws or to bring the implants into the desired form by using plates on different, sometimes small, bone grafts.

The technique presented enables the surgeon to create a stable, solid base with the calvarial bone implant. By using a wedge of irradiated rib cartilage as an onlay, fine adjustments are performed much more easily than with a piece of calvarial bone. The cartilage can be carved with a scalpel into the shape desired and provides favorable stability. Different studies<sup>20-22</sup> showed that irradiated homologous rib cartilage is a well-tolerated, safe, durable, and reliable grafting material. In patients with small-volume corrections, even a single-layer technique may be sufficient. In our experience, however, the volume correction needed in patients with enophthalmos made a double-layer technique necessary.

With the help of modern techniques, such as intraoperative navigation devices and custom-made or preformed orbital implants, surgeons will be capable of reconstructing the orbit to near-normal anatomical dimensions. These innovations should therefore improve the outcome in enophthalmos correction. As mentioned herein, there is, however, an important downside to these new tools: the cost.

The patients assessed in this study showed favorable aesthetic outcome with regard to globe positioning. Only 1 patient showed a postoperative Hertel difference of 2 mm. This finding demonstrates a difficulty of the technique presented. When performing an enophthalmos correction without the help of a custom-made implant or a navigation system, it is difficult to estimate the exact graft volume needed intraoperatively because of swelling of the eyelids and intraorbital soft tissue.

Although we knew it would be difficult to improve diplopia,<sup>5,23</sup> it was disillusioning to see that even with extensive mobilization of the orbital content and clear improvement on forced duction intraoperatively, only 1 patient showed better postoperative mobility with reduction of diplopia. Even though there was no worsening of diplopia, the functional results were unsatisfactory. Several publications<sup>24-29</sup> have discussed potential causes of persistent diplopia after surgery, and several factors such as timing of the surgical repair have been implicated as possible causes. There is, however, little evidence of the effect of timing on the outcome regarding persistent diplopia. Future investigations might clarify this point. In the same way, the effect of orbital enlargement (ie, malpositioning of the globe) on diplopia has not yet been investigated thoroughly. It seems, however, unquestionable that normal anatomical positioning of the globe is a prerequisite for normal ocular mobility. Disruption and entrapment of the orbital connective tissue system in orbital blowout fractures have been investigated by Koorneef,<sup>30</sup> who found a system of fine connective tissue ligaments



**Figure 7.** Preoperative and postoperative difference in Hertel assessments: globe position/enophthalmos.

that connects all the orbital soft tissue structures. Therefore, an incarceration of any part of the system may produce tethering by restricting the range of excursion of an extraocular muscle.<sup>25</sup> If, however, these factors were the only determinants of late ocular motility, surgical reduction should be curative, but outcome studies suggest otherwise. Harris et al<sup>25</sup> reasoned that injuries to the inferior fibrofatty-muscular complex may subsequently cause intrinsic fibrosis and contraction, tethering globe movement, despite complete surgical reduction of the herniated tissue. There are other possible mechanisms for persistent diplopia, such as direct damage to extraocular muscles,<sup>23</sup> injury to a motor nerve, or both.<sup>31</sup> These other possible mechanisms, however, are not associated with a positive forced duction test result. Nevertheless, an injury to the orbit may produce several points of damage as described herein, all of which may cause diplopia.

Iliff<sup>23</sup> published a comprehensive study on the ophthalmic implications of the correction of late enophthalmos. In this study, he retrospectively assessed 40 patients who had undergone 56 secondary repair procedures using grafted bone (50%) or alloplastic materials (50%). In 34 patients with diplopia, 50 operations had been performed. The condition had remained unchanged after 33 (66%) operations; it had worsened after 6 (12%), and it had improved after 11 (22%). We therefore believe the failure to improve diplopia in 5 of our patients is not related to the surgical technique described but is better explained as a problem of the intraorbital changes that have occurred over time. Reduction of the orbital volume to normal and mobilization of periorbital tissue must remain the goal in enophthalmos surgery. Even in patients with persistent postoperative restriction of eye motility, in whom strabismus surgery becomes necessary, the correction of the orbital volume and globe position remains a basic prerequisite.

We know only a bit about prognostic factors for residual diplopia that could be assessed preoperatively. Currently, only 1 study,<sup>32</sup> to our knowledge, has analyzed and found a correlation between swelling of extraocular muscles, measured by means of computed tomographic scans, and persistent postoperative diplopia. With the help

of new diagnostic tools, such as dynamic magnetic resonance imaging, future studies might help the understanding of these complex orbital injuries and make prognosis regarding functional outcome more predictable.

## CONCLUSIONS

The bone and cartilage wedge technique is an efficient surgical method in the correction of posttraumatic enophthalmos. It combines the advantages of 2 different implants: the stability of the bone graft as a base and the formability of the cartilage as an onlay. The 2 implants enable the surgeon to perform fine adjustments in the correction of posttraumatic enophthalmos.

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**Author Contributions:** *Study concept and design:* Lieger and Goldblum. *Acquisition of data:* Lieger, Zix, Kruse, Goldblum, and Iizuka. *Analysis and interpretation of data:* Lieger and Goldblum. *Drafting of the manuscript:* Lieger and Kruse. *Critical revision of the manuscript for important intellectual content:* Zix, Goldblum, and Iizuka. *Statistical analysis:* Lieger. *Administrative, technical, and material support:* Lieger, Zix, Goldblum, and Iizuka. *Study supervision:* Lieger and Goldblum.

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